AN EXPLORATION OF WIND-NOISE IN BUILDINGS

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INTRODUCTION

The phenomenon of wind noise in buildings is a recurring one and yet very little research into this problem has been carried out to date. This discussion paper aims to identify the dominant wind-noise sources and mechanisms produced by partly open windows in buildings as the first step towards prediction and treatment. Other examples of wind noise in buildings occur as a result of leaks in a curtain-wall or through lift shaft doors. The results presented here relate to the simulation of wind-noise through a typical window opening. A parametric study has been undertaken to establish the relationship between width of opening, sound pressure level, wind speed through the opening and the frequency (or wavelength) of the resonant peak.

The mechanisms involved in the generation of noise include air turbulence produced by the jet stream and aeolian tones set up by vortices being shed off the sharp edges of the typical window frame extrusion (eg. Powell, 1990).

EXPERIMENTAL SETUP

Wind noise generated as a result of air flow through the gap of an open window was replicated by building a full size window into the end of a wind tunnel as illustrated in Figure 1. The window was constructed using extruded aluminium window frame members shown in Figure 2. The opening to the wind tunnel was otherwise fully sealed using a Masonite timber panel. Operation of the wind tunnel fan created a pressure differential across the opening similar to what one would expect in the real world from wind induced pressures.

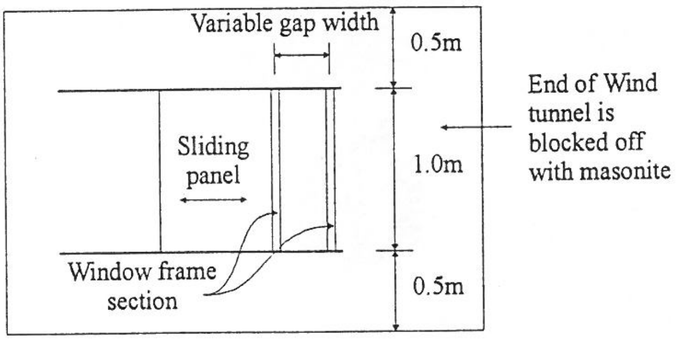

Figure 1: Experimental setup to replicate wind noise due to window openings.

Differential pressures were not measured in this experiment. However, Wassef *et al* (1985) indicates that the noise amplitude generated by air flow in gaps tends to increase once the pressure differential exceeds 450kPa and that differential pressures have almost no effect on the noise frequency for gap widths greater than 2.5mm.

Measurements of third octave band noise spectra were obtained using a Norsonic SA110 sound level

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meter. Simultaneous recordings were made of the width of the window opening, the mean wind speed through the opening (in the centre of the gap) and the frequency of the wind generated tone (where this existed). The Norsonic SA110 sound level meter was positioned as a distance of 1m from the centre of the gap and at 45 degrees to the side in plan view. An HP3561A narrow band spectrum analyser was used to determine the predominant frequency of the aeolian tones generated.

Profiles of the typical window extrusion and the smooth extrusion are shown in Figure 2. Tests were also undertaken for a smooth extruded aluminium frame member as shown in the Figure.

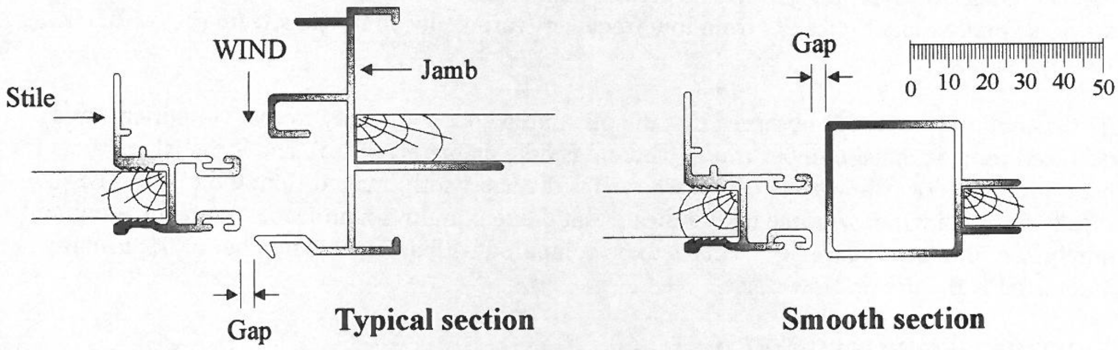

Figure 2: Profiles of the aluminium window frame extrusions.

RESULTS AND DISCUSSION

Sample third octave spectra for the typical section are shown in Figures 3a and 3b. Noise produced by the wind tunnel fan and air turbulence in the wind upstream of the test panel was measured with the window gap fully open and subtracted from the spectrum derived for the test apertures. This corrected as much as possible for fan noise contribution. Both A-weighted and linear third octave spectra are shown in the Figures.

Figure 3c shows a typical result for the smooth section. In this case, the onset of aeolian tones did not occur for gap widths greater than 10mm whereas with the typical section, tones were identified up to 50mm. From this we conclude (as expected) that the presence of sharp edges facilitates the generation of aeolian tones.

Initial results indicate that the onset of aeolian tone generation for the typical section occurs at a critical wind speed, V_{cr}, related to the width of the gap as demonstrated in Figure 4a. The frequency of the generated tone is then proportional to the wind speed as shown in Figure 4b. This result reflects experience observed in real life, that the pitch of the tone generated by the wind is related to its strength.

Figures 4c and 4d show the dependence of tone wavelength and frequency of the aeolian tone as a function of gap width. For gap widths of 50mm and less, a linear relationship is evident between gap width and wavelength according to the following relationship;

$$\text{Wavelength } \lambda = C/f = 31.5b, \quad \text{where b is the gap width}$$

Theoretical and experimental work on noise caused by wind flow tangential to circular holes, by Parthasarathy *et al* (1985) for flow velocities between 40.8 and 81.6m/s concluded that the wavelength, λ is proportional to the effective depth [= depth of the hole (D) + a fraction of the diameter of the hole(d)]. However, this relationship is not true of flow through window openings because the mechanism of noise generation is different.

Figure 4e shows that the sound pressure level (SPL) of the generated tone increases with increasing wind speed and, for the same wind speed, increases with decreasing gap width. Figure 4f shows that for small gap-widths less than 50mm, the over-all noise level is dominated by aeolian tones, however, for gap widths greater than 50mm (where aeolian tones were not present), the noise predominantly results from low frequency turbulence in the jet stream (below 63Hz, eg. see Figure 3a).

Parthasarathy *et al* (1985) observed that the maximum sound intensity from a cylindrical cavity occurred for a Strouhal number (f.d/u, where d is hole diameter) of 0.5. The Strouhal numbers for the typical window frame tests (f.b/u, where b is the gap width) ranged from 0.6 to 1.6. The results from the window frame tests indicate that the maximum sound levels occur for Strouhal numbers of 0.8 (see Figure 4g). This is to be compared with a Strouhal number of 0.2 usually associated with pure jet flow noise.

FURTHER WORK REQUIRED

Further work is required to establish the mechanisms of flow noise involved, the effect of wind speed on the frequency of the resonant peak, particularly for the smaller gap widths. The effect of higher wind speeds (for Strouhal numbers down to 0.2) also needs to be investigated.

This paper addresses wind-noise caused by flow through the window opening. The effect of wind noise due to wind moving across a window opening is yet to be investigated.

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Mr Henky Mantophani of Sydney University undertook the experimental work for this study as part of his Mechanical Engineering final year thesis. The contributions of both Henky and his supervisor, Dr John Atkinson are acknowledged.

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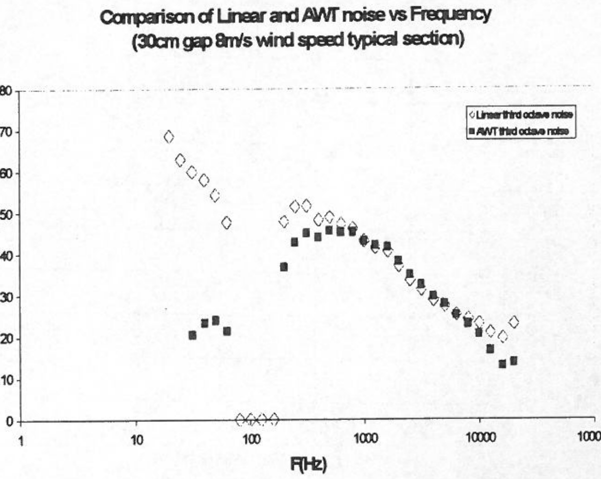

Figure 3a

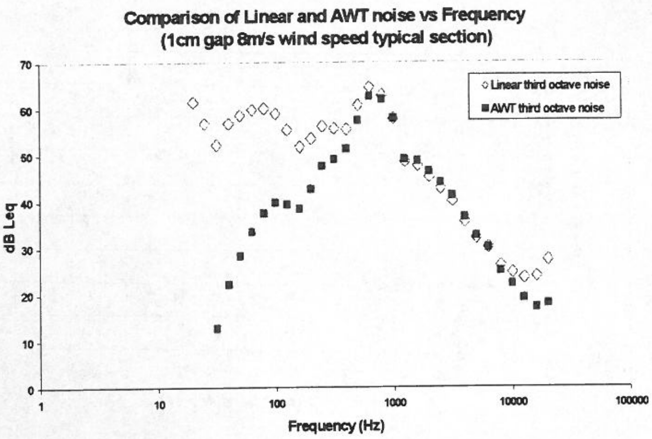

Figure 3b

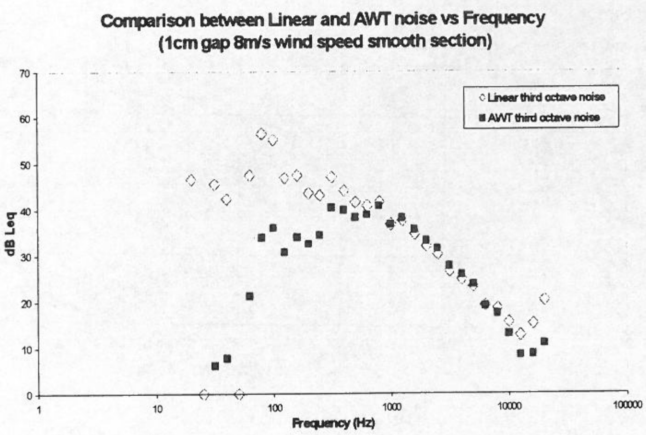

Figure 3c

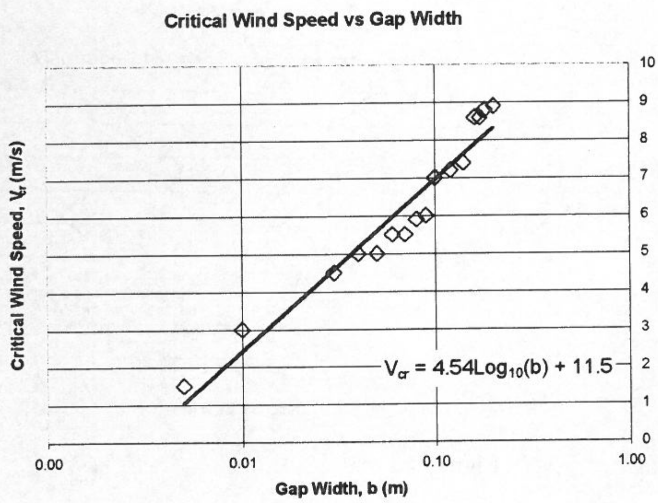

Figure 4a

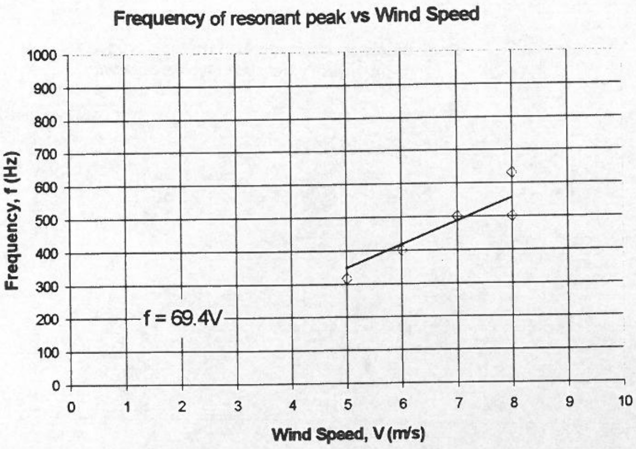

Figure 4b

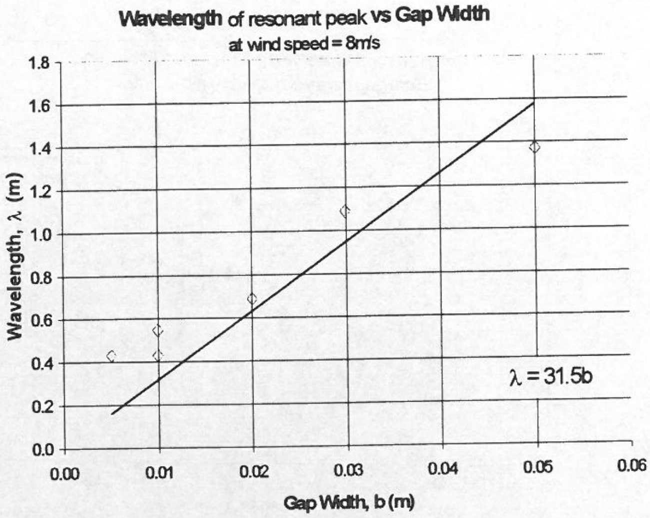

Figure 4c

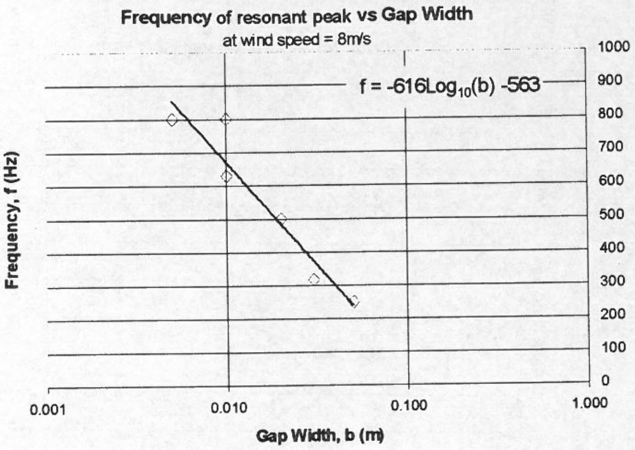

Figure 4d

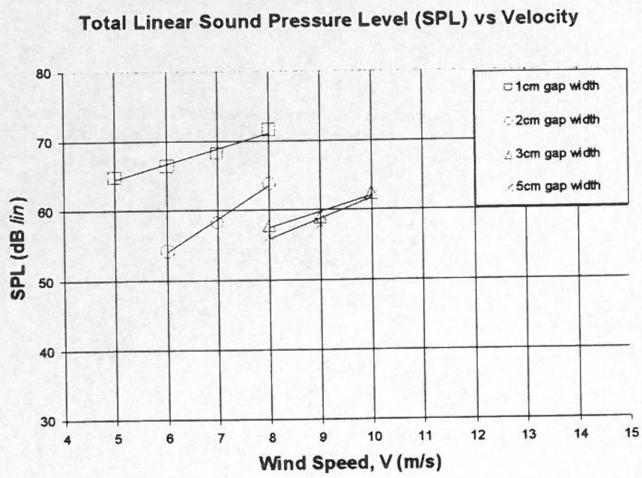

Figure 4e

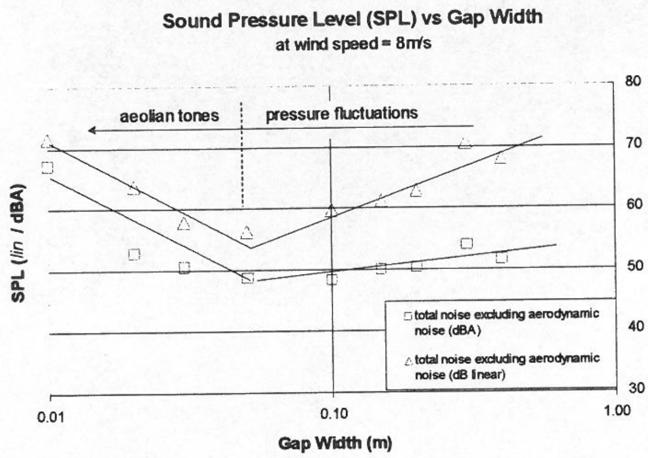

Figure 4f

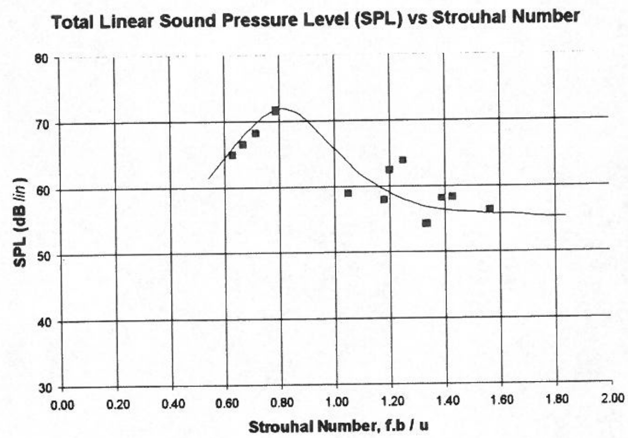

Figure 4g